

The present invention relates to apparatus for loading a substrate onto a processing surface in a thin-film processing chamber.

5 Thin-film processing chambers are used for processing substrates, such as silicon wafers, by either etching the substrate or depositing additional material onto the substrate. Such processing chambers include a processing surface onto which the substrate must be loaded before
10 processing. These substrates are generally very delicate in nature and it is therefore important that the loading procedure does not subject the substrate to undue levels of stress which result in the substrate becoming damaged.

One example of loading apparatus that has previously
15 been used is shown in Figure 1A. This comprises of a processing chamber 2 including a support 17 which projects through an aperture 19 of a processing surface 16. The support 17 includes three arms 18 which extend vertically upwards from the support 17 so as to contact the underside
20 of a substrate 15, as shown. In use, once the substrate 15 is positioned on top of the arms 18 the support 17 is lowered to the position shown in Figure 1B so that the substrate 15 is lowered on to the processing surface 16.

In general, whilst the substrate 15 may be placed on
25 the arms 18 by hand, a loading arm is preferably used to aid the loading procedure. An example of such a suitable loading arm system is shown in Figure 2.

In this case, the processing chamber is coupled to a loading chamber 3 via a valve 4. Before loading commences,
30 the substrate 15 is manually loaded onto a substrate holder 1. The loading chamber 2 is then evacuated so it is at the same pressure as the processing chamber 2 and the valve 4 is opened.

The substrate holder 1 is fixed to a distal end 5 of
35 a loading arm 6. The arm 6 extends from the rear of the loading chamber 3 into a loading arm chamber 7 (also evacuated). The rear end of the loading arm chamber 7 is

fitted with a suitable magnetic material 8 which is attracted to a cylindrical magnetic slider 9 which is slidably mounted to the exterior of the loading arm chamber 7. The substrate holder 1 is then transferred into the processing chamber 2 by manually sliding the magnetic slider 9 as indicated at 11.

This causes the loading arm 6 to move with the slider 9, consequently causing the substrate holder 1 to move into the loading position as indicated by dotted lines at 10. The distance of travel 12 of the substrate holder 9 is limited by the allowable extent of travel 13 of the slider 9.

Once the loading arm 6 is positioned in the processing chamber 2, the support 17 is raised from the retracted position shown in Figure 1B. As shown in Figure 2, the substrate holder 1 includes a recess 1a which is configured such that as the support is raised, the arms 18 pass through the recess 1a and engage the underside of the substrate 15. This action raises the substrate 15 clear of the substrate holder 1 such that the loading arm 6 may be removed from the processing chamber, whilst the substrate 15 remains supported by the arms 18. The support 17 is then lowered to the position shown in Figure 1B to leave the substrate 15 in contact with the processing surface 16.

Unfortunately, such a system has the disadvantage that the arms 18 contact the lower surface of the substrate 15. As mentioned above, the substrates are particularly delicate and this operation can therefore cause significant damage to the substrate.

In accordance with the present invention, we provide apparatus for loading a substrate onto a processing surface in a thin-film processing chamber, the apparatus comprising a support which cooperates with one or more corresponding apertures in the processing surface so as to be movable between an extended position in which the support can support a substrate above the processing surface, and a retracted position in which the support is flush with or

located below the processing surface, wherein the support comprises a number of limbs extending radially outwardly from a central hub, at an angle relative to the processing surface, the limbs being configured to contact the edges of different sized substrates in use so as to support the substrate in a support plane substantially parallel to the processing surface, the support plane being provided above the central hub.

Accordingly, the present invention provides apparatus for loading a substrate onto a processing surface which does not contact the lower surface of the substrate. Instead, the limbs of the support are designed to contact the edges of the substrate whilst supporting the substrate substantially parallel to the processing surface. The support can then be lowered allowing the substrate to be gently placed on the processing surface. Furthermore, by having the limbs extend at angle offset to the processing surface, the limbs can be used to support any size of substrate.

Typically each end defines a continuous support surface extending at an angle relative to the processing surface, each support surface contacting the edges of different size substrates in use. The use of the angled support surface allows a simple construction to be used which can support any size of substrate and allow this to be easily loaded onto the processing surface. Alternatively however each limb may define a number of support surfaces, with each support surface being associated with a respective support plane. In this configuration, the limb will effectively consist of a number of steps with the corresponding steps of each limb being configured to accept a different size of substrate. This again allows different sizes of substrate to be easily loaded on to the processing surface.

Typically the apparatus further comprises a loading arm having a mounting which receives a substrate in use, the loading arm being movable between the retracted

position and an extended position in which the mounting and support cooperates such that, in use, motion of the support to the extended position causes the substrate to be supported by the support, thereby removing the substrate from the mounting. As will already be realised, this provides apparatus having a simple construction which allows the substrate to be automatically loaded onto the processing surface within the processing chamber. However, any suitable means for placing the substrate on to the support, such as hand loading, or the use of a robotic arm, may be used. In the case in which a robotic arm is used, the robotic arm is typically arranged with a number of processing chambers circumferentially spaced around it, thereby allowing the arm to be used to load substrates into a number of different processing chambers in turn.

Typically the mounting comprises a number of mounting elements extending radially outward from a central portion, each mounting element defining a number of mounting surfaces and each mounting surface being associated with a respective mounting plane. In this configuration, each mounting element will effectively consist of a number of steps, with each step defining a mounting surface. The corresponding mounting surfaces of each limb are then configured to accept a different size of substrate so that a separate mounting position is defined for each different size of substrate that is to be used. In use, the substrate is positioned on the steps defined by the mounting surfaces, thereby ensuring that the substrate is in the optimum position for subsequent processing. It will however be realised that alternative designs could be used.

The apparatus further comprises a drive means for controllably moving the loading arm between the extended or retracted positions. Alternatively however the loading arm may be simply moved by hand.

Typically, apparatus further comprises an actuator for controllably moving the support between the extended and retracted positions. This advantageously allows the

substrate to be gently lowered onto the processing surface to thereby further reduce the risk of damage to the substrate.

5 Preferably the apparatus further comprises a clamp movable between an open position and a clamping position for clamping the substrate to the processing surface. This allows the substrate to be held in position whilst processing occurs. It will however be realised that this will not be essential in all circumstances.

10 Typically the clamp comprises an annular clamping element extending radially inwardly from an outer clamping ring the clamping ring being positioned radially outwardly from the processing surface. This allows the clamp to be configured to only touch the outer edge of the substrate, thereby reducing the amount of damage that can occur to the
15 substrate, during processing.

The use of an annular clamping element ensures that the substrate is clamped along the entire circumference of its upper surface. This ensures that a strong clamping
20 force can be applied evenly to the substrate thereby ensuring that the substrate is held in place. Furthermore by ensuring that the clamping force is even over the entire surface of the substrate, this helps prevent bending or fracturing of the substrate by the clamping element.

25 However, if less clamping force is required it is also possible to use a number of separate clamping elements each of which extends radially inwardly from the outer clamping ring. In this case, typically three elements would be provided circumferentially spaced around the annular
30 clamping ring so that the substrate is clamped at three positions around the circumference of its upper surface. This will however generally provide less clamping force and provides an increased risk of fracture during use.

Typically the apparatus further comprises a clamp
35 actuator for moving the clamp between the open clamping positions, the clamping ring being removably mounted to the clamp actuator. This allows the clamp to be configured to

automatically clamp the substrate when it is in position on the processing surface. Furthermore, the clamping ring can be removed from the actuator and replaced with a clamping ring having alternative clamping elements. This allows
 5 substrates of different sizes to be suitably clamped to the processing surface.

Typically the apparatus further comprises a controller for control of the moving support on the loading arm between their respective retracted unextended positions.
 10 This allows the substrates to be automatically loaded onto the processing surface, thereby removing the need for operator intervention.

Conveniently, the apparatus further comprises a loading assembly having a mounting which receives a
 15 substrate in use, the loading assembly being movable between a retracted position in which the mounting is outside the processing system chamber and an extended position in which the mounting is inside the processing system chamber, and wherein the mounting comprises a number
 20 of mounting elements extending substantially radially outwardly from a central position, each mounting element defining a number of mounting surfaces, and each mounting surface being associated with a respective mounting plane, and wherein the mounting and the support cooperate such
 25 that, in use, with the loading assembly in the extended position, motion of the support to the extended position causes the substrate to be supported by the support, thereby removing the substrate from the mounting.

Accordingly, the present invention also provides
 30 apparatus for loading a substrate into a thin-film processing system chamber which comprises a loading assembly having a mounting which receives the substrate. The mounting includes a number of mounting elements each of which defines a number of mounting surfaces by using a
 35 stepped arrangement. Each mounting surface is associated with a respective mounting plane and is designed to accept different sizes of substrate. The system is arranged in

this configuration so that a separate mounting position is defined for each different size of substrate to be used. Accordingly, by mounting a substrate in the respective mounting plane defined by the appropriate mounting surfaces, this ensures that the substrate is always located in the optimum position for subsequent loading in to the processing chamber and subsequent processing.

In this situation, with the mounting designed to hold the substrate in the correct position, this ensures that the substrate is correctly loaded onto the processing surface.

Thus, the mounting is adapted so that in use a substrate positioned on the mounting in the respective mounting plane will be located substantially over the centre of the processing surface when the loading assembly is in the extended position.

The apparatus usually further comprises a drive means for controllably moving the load and between the extended retracted positions.

In this case, the loading assembly typically comprises a carriage, first drive means for driving the carriage with respect to a base, a second drive means which moves with the carriage and cooperates with the base whereby the relative movement between the carriage and the base causes the second drive means to drive the mounting with respect to the carriage. However, this is not essential and any suitable loading assembly, such as a loading arm or robotic arm may be used.

When the above mentioned configuration is used the current is slidably mounted to the base and the mounting is slidably mounted to the carriage.

Accordingly, the present invention also provides a thin film processing system comprising one or more processing chambers in which substrates are processed and a loading apparatus according to the present invention.

Examples of the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1A and 1B show apparatus for loading a substrate according to the prior art;

Figure 2 shows a loading arm according to the prior art;

5 Figure 3 shows a plan view of a first example of a substrate loading apparatus according to the invention;

Figure 4 shows a cross section along the line A-A' of the apparatus of Figure 3 in its retracted position;

10 Figure 5 shows a cross section along the line A-A' of the apparatus of Figure 3 in its extended position;

Figure 6 shows a loading arm, suitable for use with the apparatus of Figure 3, in its retracted position;

Figure 7 shows the arm of Figure 6 in its extended position;

15 Figure 8 is a cross-section of Figure 6 along a line B-B';

Figure 9 shows a cross section along the line B-B' of the apparatus of Figure 2 in its extended position in conjunction with the loading arm of Figure 6;

20 Figure 10 shows a plan view of a second example of a substrate loading apparatus according to the invention;

Figure 11 shows a cross section along the line C-C' of the apparatus of Figure 10 in its retracted position;

25 Figure 12 shows the apparatus along the line C-C' of Figure 10 in its extended position;

Figure 13 shows a perspective view of Figure 11;

Figure 14 shows a perspective view of Figure 12;

Figure 15 is a plan view of a processing surface of a third example of the present invention;

30 Figure 16 shows a cross-section along the line D-D' of the processing surface of Figure 15;

Figure 17 is a cross-sectional view of a processing chamber according to a fourth example of the present invention; and,

35 Figure 18 shows a perspective cut-away view of the apparatus of Figure 17.

An example of loading apparatus according to the present invention will now be described with reference to Figures 3 to 5.

Figure 3 shows a plan view of a thin-film processing chamber 60. The chamber 60 includes a processing surface 61 upon which a substrate, indicated by the dotted lines 65, is placed. The processing surface 61 includes an aperture 62 within which is located a substrate support 66. The substrate support 66 is formed from three support limbs 64 which extend radially outwardly from a central hub 63. The processing chamber 60 may optionally also include an interface 69 to allow access to the processing surface 61.

Figure 4 shows a cross-section along the line A-A', when the substrate support 66 is in its retracted position. As shown, the substrate 65 lies on the processing surface 61 with the support limbs 64 being positioned either flush with, or below the processing surface 61. The central hub 63 of the substrate support 66 is coupled via a shaft 67 to an actuator, which is shown schematically at 68.

The actuator may be any suitable drive means which can impart vertical motion to the shaft 67. However, preferably it will comprise an air cylinder device coupled to the shaft 67 such that when air is pumped into the cylinder, this will cause the shaft 67, and hence the substrate support 66, to rise into the extended position shown in Figure 5. In this position, the substrate 65 is supported by the support limbs 64.

As shown, the upper surface of the support limbs are provided at an angle with respect to the processing surface 61. Accordingly, the central hub 63 of the substrate support 66 is at a lower height than the outer end of the support limbs 64. As a consequence, the substrate 65 is supported by the edges of the substrate contacting the support limbs 64, as shown. As a result, the central hub 63 is positioned below the substrate 65 and there is no contact of any part of the substrate support 66 with the underside of the substrate 65.

In use, the actuator 68 will initially be actuated to move the substrate support 66 into the extended position. The substrate 65 is then placed on the substrate support 66, as shown in Figure 5. The actuator is then operated to
 5 cause the substrate support 66 to gently lower into the retracted position. As a result, the substrate 65 is gently lowered onto the processing surface 61, as shown in Figure 4. It will be realised that such operation ensures that the underside of the substrate 65 is protected from
 10 damage as there is no contact with the substrate support 66.

In the above mentioned example, the substrate 65 is positioned on the substrate support 66 by hand. However, it is also possible for a loading arm to be used to load
 15 the substrate into the processing chamber. This would generally be achieved by having the loading arm positioned in a loading chamber so as to receive the substrate. The loading arm can then be extended into the processing chamber to position the substrate 65 on the substrate
 20 support 66.

An example of a suitable loading arm will now be described with reference to Figures 6 to 8.

Figure 6 shows a loading arm chamber 20 comprising a standard interface 21 conforming to the SEMI E21-91
 25 standard. This allows the chamber 20 to be mounted in use to any suitable processing chamber interface such as the interface 69 of Figures 3 to 5. Before evacuating the loading chamber 20, a substrate 65 (indicated in dotted lines) such as a wafer is placed on a substrate mounting
 30 24. The position of the clean-room interface when fitted is indicated at 22. The lid of the loading chamber is removed for clarity.

Figure 7 shows a plan view of the loading apparatus in its extended loading position. Figure 8 is a cross-section
 35 of Figure 7 along a line B-B'. Substrate mounting 24 is slidably mounted on carriage 25 via a conventional linear

bearing. Carriage 25 is slidably mounted on fixed rail 26, also via a conventional linear bearing.

Carriage 25 is mounted with pulleys 29,30 which rotate about axles 31 and 32 respectively. A drive belt comprising a closed loop of steel belt or wire 33 passes round the pulleys 29,30 and is fixed to the loading chamber 20 at 34, and to the substrate support 24 at 35. Therefore, linear movement of the carriage 25 (and associated pulleys 29,30) in the loading direction causes the pulleys to rotate clockwise (due to the fixing point 34). The combined linear movement of the arm 25, and driven movement of the steel belt or wire 33, causes the lefthand side 36 of the wire loop to move twice the speed and distance of carriage 25. Hence the substrate mounting 24, attached to the lefthand side 36 of the steel belt or wire 33 at fixing point 35 has a transfer distance 37 which is twice the transfer distance 38 of the carriage 25.

The telescopic movement and use of mechanical advantage allows a compact loading chamber. As can be seen from Figure 2, the substrate mounting 24 and carriage 25 have approximately the same length in the loading direction, and in its retracted position the substrate mounting 24 lies in register with the carriage 25. This provides a particularly compact construction.

Carriage 25 is driven by a pulley drive arrangement comprising a first drive pulley 40, a second driven pulley 41 and a closed loop of steel belt or wire 42 which passes round the pulleys 41,40. The steel belt or wire 42 is attached to the arm 25 at 43. Therefore, rotation of the drive pulley 40 in an anti-clockwise direction causes the arm 25 to move in the loading direction. The drive pulley 40 is driven by a drive motor 50 shown in Figure 4. Figure 4 also shows the layered relationship of the slide rail 26, carriage 25 and substrate support 24.

Optical detectors 44,45 detect the presence of a hole 46 in the belt or wire 42 to indicate that the arm 25 has reached its extended or retracted position. In the

extended position of Figure 7 the hole has been detected by the detector 44. At this point, the detectors send a signal to motor 50, which causes it to stop rotating the drive pulley 40. If the optical detectors 44,45 fail to work, the extent of movement of carriage 25 is ultimately limited by mechanical stops 27,28.

One or both of the drive belts 33,42 may be mounted vertically, instead of horizontally as shown in Figures 2 to 4.

A typical sequence of events in a thin film processing system incorporating the loading assembly according to the invention will now be described with reference to Figure 9.

Before operation, the wafer support is fully retracted into the loading chamber. To load a wafer into the process chamber, the following sequence of events occurs:

1. The operator opens the loading chamber door, places the substrate 65 onto the substrate mounting 24, then closes the load lock door.
2. The loading chamber is pumped down to base pressure.
3. The pneumatically operated interface 69 is opened.
4. The loading arm extends into the processing chamber 60.
5. The substrate 65 is lifted from the substrate mounting 24 by the substrate support 66 to its extended position, as shown in Figure 9. The substrate mounting 24 is withdrawn from the chamber, and the substrate 65 is lowered onto the processing table by the substrate support 66.
6. As the substrate support reaches its fully retracted position within the loading chamber, the hole in steel belt 42 is detected by the photo diode to stop the DC motor 50.
7. The interface 69 is closed and the load lock can be vented if required.

The above sequence of events is repeated to remove the wafer from the processing chamber.

Figures 10 to 14 show a second example of a substrate loading apparatus according to the present invention. The apparatus shown in these diagrams is substantially the same as the apparatus of Figures 1 to 9 with a number of modifications.

As shown in Figure 10, the apparatus comprises a thin-film processing chamber 160 having a processing surface 161 including an aperture 162. A substrate support 166 is mounted within the aperture, the substrate support including a number of support limbs 164 extending radially outwardly from a central hub 163. As in the previous example, the central hub 163 is coupled via a shaft 167 to an actuator 168 so as to allow the substrate support 166 to move between the retracted position shown in Figure 11 and an extended position shown in Figure 12.

The first modification shown in Figure 10 is the use of a modified substrate mounting 124 which is mounted to a loading arm which can be of any suitable design, such as the loading arm arrangement shown in Figures 6 to 8.

The substrate mounting 124 includes a number of mounting elements 180 which are coupled to the substrate mounting 124 as shown in Figure 10. A side view of the modified substrate mounting 124 is indicated by the dotted lines in Figure 12. As shown, the mounting elements 180 include a number of steps 181 which define a number of support surfaces 182. The mounting elements 180 are arranged so that the respective support surfaces 182 of the different mounting elements 180 cooperate to support the substrate 165. As will be realised, different sized substrates will be supported on respective different surfaces 182, with lateral motion of the substrate 165 on the support surfaces being constrained by the step 181. As a result, a given size of substrate 165 will always be supported in the same location on the substrate mounting 124. This helps ensure that the substrate 165 will always

be loaded onto the processing surface 161 at a desired position.

As in the previous example, the substrate support 166 is moved to the extended position once the substrate mounting 124 has been positioned over the processing surface 161. This causes the substrate 165 to be raised clear of the substrate mounting 124, as shown in Figure 12. The loading arm is retracted so as to move the substrate mounting 124 out of the processing chamber, thereby allowing the substrate support 166 to be lowered. This loads the substrate 165 onto the processing surface 161.

The second modification, which is shown in Figures 10 to 14, is the addition of a clamping system for holding the substrate 165 in position on the processing surface 161. The clamping system comprises a clamp ring 191 which is removably mounted to a support 190. The clamp ring 191 includes three shaped apertures 192 which couple to fixings 193 which are fixably mounted to the support 190. Rotation of the clamp ring 191 causes the fixings 193 to align with the larger end of the aperture 192 so that the clamp ring 191 can be lifted free of the support 190.

Coupled to the clamp ring 191 are three brackets 194 which extend vertically upwards from the ring 191. Two of the brackets 194 are shown in Figure 11. Mounted to each bracket 194 is a resilient clamping member 195 which extends radially inwardly from the bracket 194 so as to contact the processing surface 161. These clamping members are generally formed from a plastic material, or the like, which allows the end of the clamping member to flex with respect to the bracket 194.

The support 190 is coupled to an actuator, which is shown schematically at 196. The actuator 196 allows the support to be moved between an open position, shown by the dotted lines in Figure 12 and a clamping position shown in Figure 11.

In the clamping position, the resilient clamping members 195 contact the edge of the upper surface of the

substrate 165 thereby holding the substrate in place on the processing surface 161. As will be understood, the clamping members 195 are designed to flex slightly so as not to crush the substrate whilst still applying sufficient pressure to prevent motion of the substrate 165 with respect to the processing surface 161. When the actuator 196 is activated, this raises the support 190 to the open position shown in Figure 12 so that the resilient clamping members 195 are lifted clear of the substrate 165. This allows the substrate 165 to be raised, as shown in Figure 12.

It will be realised that for different size substrates 165, the clamping members 195 need to be of different lengths. Accordingly, when the size of substrate 165 to be used is altered, the clamping ring 191 is twisted and removed from the support 190 as described above. An alternative clamping ring with different size clamping members 195 is then fitted to the support 190 as required by the alternative size of substrate 165.

The third modification to the apparatus is the addition of a pressure regulator 200 which is coupled to a pipe 201 which surrounds the shaft 167. The pipe 20 is used to allow helium to flow into the aperture 162 under the control of the pressure regulator 200 of the processing surface 161. This is performed to enhance heat transfer between the substrate and the processing surface 161, when the substrate 165 is lowered onto the processing surface.

A third example of the present invention is shown in Figure 15. In this example, a modified processing surface 261 is provided for use in a thin film processing chamber. The processing surface 261 includes an aperture 262 and a substrate support 266 mounted within the aperture. The substrate support includes a number of support limbs 264 extending radially outwardly from a central hub 263.

As in the previous examples, the central hub 263 is coupled via a shaft 267 to an actuator 268 so as to allow the substrate support 266 to be moved between a retracted

position, which is shown in cross-section in Figure 16, and an extended position (not shown).

As in the previous example, a pressure regulator 300 is provided which is coupled to a pipe 301. In this example, the pipe 301 extends up through the processing surface 261 to a number of inlet holes 302 which are shown in Figure 15. As shown, the inlet holes 302 are circumferentially spaced apart around the aperture 262. In use, a substrate 265 which is to be etched will cover the inlet holes 302, as shown.

As in the previous example, the pressure regulator 300 is used to allow helium to flow into the pipe 301 and through the inlet holes 302. As the film processing chamber 260 is generally maintained at near vacuum pressures, the helium will simply flow into the chamber through the inlet holes 302 causing any air caught between the substrate 265 and the processing surface 261 to be expelled. The inlet holes 302 are positioned away from the aperture 262 to reduce the dissipation of helium through the aperture 262.

An example of a fourth embodiment of the present invention will now be described with reference to Figures 17 and 18. In this example, the clamping arrangement formed from the clamping members 195, shown for example in Figures 11 and 12, is replaced with an annular clamping arrangement.

Thus, as shown, a thin film processing chamber 360 having a processing surface 361 is provided with an aperture 362. A substrate support 366 is mounted within the aperture, the substrate support including a number of support limbs 264 extending radially outwardly from a central hub 363. The central hub 363 is coupled via a shaft 367 to an actuator 368 so as to allow the substrate support 366 to move between retracted and extended positions, as shown for example in previous embodiments.

In this example, a clamping system is provided for holding the substrate 365 in position on the processing surface 361.

The clamping system comprises a clamp ring 391 which is movably mounted to a support 390. The clamp ring 391 includes three shaped apertures (not shown but similar to the apertures of 192 shown in Figure 13) which couple to fixings 393 which are fixably mounted to the support 390. Rotation of the clamp ring 391 causes the fixings 393 to align with the larger end of the aperture so that the clamp ring 391 can be lifted free of the support 390.

Coupled to the clamp ring 391 are a number of brackets 394 which extend vertically upwards from the ring 391. The brackets are mounted at their upper end to an annular wafer clamp 395 which is held in place by a retaining ring 397.

The wafer clamp 395 extends radially inwardly from the brackets 394 as shown.

In use, the support 390 is coupled to an actuator 396 which allows the support 390 to move between an open position (not shown) and a clamping position shown in Figure 17.

In use, the support 390 is raised, as in the second embodiment to allow a substrate 365 to be positioned on the support surface 361. The actuator 396 is then operated to lower the support 390 into the clamping position. At this time, the wafer clamp 395 contacts the upper surface of the substrate 395 to hold it in place.

Because the wafer clamp 395 is an annulus, this ensures that the clamping pressure is provided around the entire circumference of the substrate 365. This provides a more secure clamping mechanism than the clamping mechanism of the second embodiment shown in Figures 10 to 14. In addition to this, as pressure is exerted evenly around the entire circumference of the substrate 365, this helps prevent the substrate being cracked by differences in pressure along its upper surface.

Again, as in the second embodiment it is possible to use different size of wafer clamp 395 when different sizes of substrate 165 are clamped.

5 It will be realised by a person skilled in the art that any of the modifications described in the second, third and fourth embodiments may be implemented separately or in any combination. The description of all the modifications within the four examples is for the case of description only and is not intended to be limiting.

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217